THE PERMIAN CONODONT BIOCHRONOLOGY. PROGRESS AND PROBLEMS

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The Permian–Triassic boundary (PTB) can be defined with the first appearance datum (FAD) of *Hindeodus parvus* within the phylomorphogenetic lineage *H. typicalis–H. latidentatus praeparvus–H. parvus*. The advantages of this boundary are: (1) The FAD of *H. parvus* lies within a known phylomorphogenetic lineage. (2) *H. parvus* occurs both in ammonoid-free shallow-water limestones and in deep-water sediments. (3) *H. parvus* occurs in all faunal provinces, both in low latitude warm-water deposits and in high latitude cold-water deposits.

The base of the Asselian (= base of the Permian, FAD of *Streptognathodus isolatus*) and the base of the Kungurian (if defined with the FAD of *Neostreptognathodus pnevi*) are correlatable world-wide in marine deposits. The base of the Sakmarian and of the Artinskian are so far not well defined. The base of the Roadian is defined with the FAD of *Mesogondolella nankingensis* that is contemporaneous with the FAD of *Mesogondolella saraciniensis* and *M. gracilis* in the smooth *Mesogondolella* lineages. Within the Wordian and Capitanian, the warm-water serrated *Mesogondolella* and the cool-water (or cold bottom-water) smooth *Mesogondolella* lineages are not well correlated. The base of the Lopingian Series (FAD of *Clarkina postbitteri*) is not yet well defined because this species is absent in the Boreal realm, western and central Tethys, and in the eastern Tethyan it is an immigrant that replaces suddenly the serrated *Mesogondolella*. Its forerunner, *Clarkina crofti*, is so far only known from Texas. A definition of the base of the Lopingian with the FAD of *Clarkina altudaensis* would allow the recognition of this boundary within the phylomorphogenetic lineage *Mesogondolella shannoni–C. altudaensis* both in the Tethys and in western North America. The base of the Dzhulfian s.s. is well defined by the FAD of *Clarkina leveni* that developed from *C. niuzhuangensis*. The base of the Dorashamian is defined by the FAD of *C. subcarinata* that evolved from *C. longicuspidata*. Both boundaries are so far only precisely recognisable in the Tethyan pelagic faunas because the exact correlation with the Boreal conodont fauna and with the Tethyan shallow-water successions are unknown. Between the top of the Capitanian and the base of the Dzhulfian s.s., there are 2–3 major conodont zones (depending on the final definition of the base of the Lopingian). The introduction of a new stage or the restriction of a revised Abadehian Stage to this time interval is favoured.

The Dzhulfian *Mesogondolella britannica* sp. nov. is described and the synonymy of *Stepanovites* and *Sweetina* is explained.

ADVANTAGE AND PROBLEMS OF THE CONODONT CHRONOLOGY

CONODONTS are the best suited fossils for definition of most Permian stages and substages because they are less affected by provincialism than all the other stratigraphically important fossils. However, they are absent from major areas with cold-water deposits, e.g. in Asselian glaciomarine deposits of Gondwana and in Permian cold-water deposits of northeast Siberia. The known Lower Permian conodonts have at the same water depth nearly the same faunal composition. However, in high latitude Gondwana marine deposits they are missing in the Asselian–Sakmarian (too low water temperature). The Asselian *Gondolellodies cnadiensis* is restricted to the Boreal realm that had in that time a rather warm climate with marine

algae, fusulinids and corals. In the Artinskian–Kungurian, a low-diversity *Vjalovognathus* fauna occurs in eastern Gondwana (Western Australia; Nicoll & Metcalfe 1997). The latter genus is also present in moderate to high diversity conodont faunas of the eastern Perigondwana margin (Kozur 1995a). From western Gondwana (Bolivia) through North America and the Tethys to Svalbard identical pre-Kungurian Lower Permian conodont faunas occur in similar facies. During the Kungurian, the conodont provincialism became somewhat stronger. For instance, *Neostreptognathodus pnevi* Kozur & Movshovich is only known in the Boreal realm and in areas that were connected with the Boreal realm, as the Cis-Ural, in the Phosphoria Basin and very rarely in Texas (Movshovich et al. 1979; Wardlaw 1983; Behnken et al. 1986), whereas *N. exsculptus* Igo is present in the Tethys, in the

Cireum-Paeific area and in western North Ameriea, but missing in the Cis-Urals and in the Boreal realm (Kozur 1996a).

During the Middle and Late Permian, the warm-water and eool-water eonodont faunas are totally different. The eool-water faunas do not just oeeur in high latitudes, but also in open-sea environments in the tropieal Tethys, if the water depth was below 200 m and the areas were eonneeted to the eold bottom-water eurrents as indieated by the presenee of palaeopsyehrospherie ostraeods (Kozur 1991a). Consequently, all Tethyan Guadalupian open-sea pelagie faunas have eool-water eonodont faunas without serrated, but only with smooth *Mesogon-dolella*. The same problems with the eonodont eorrelations exist during the Lopingian. The *Clarkina leveni* lineage, to whieh belong all zonal index forms of the tropieal pelagie Tethyan Lopingian, is restrieted to warm-water and partly to warm temperate water. In eontrast, *Mesogon-dolella britannica* sp. nov. and *Merrillina divergens* (Bender & Stoppel) eharaeterise the Dzhulfian high latitude eool-water to eool-temperate faunas (that may invade also those low latitude areas that have only a eonneetion to the Boreal sea), and the eool-water Dorashamian is eharaeterised by *Clarkina* of the *C. carinata group* that invaded the eentral and western Tethys only in the Lower Triassie *Isarcicella isarcica* Zone. With exeeption of the base of the Guadalupian and the Permian–Triassie boundary (PTB), the eorrelations of the warm- and eool-water faunas are not yet well understood.

Hindeodus and *Merrillina* oeeur both in warm- and eold-water deposits, but *Hindeodus* has short-ranging speeies only during the uppermost Permian and lowermost Triassie, whereas *Merrillina* needs a thorough taxonomie revision before it ean be applied to stratigraphie eorrelations.

The pelagie and shallow-water eonodont faunas are also very different, but in slope sediments both types may oeeur together. In the Lower Permian Cis-Uralian Series, both shallow-water and deep-water eonodonts are well suited for stratigraphie subdivisions and eorrelations. During the Middle and Late Permian, exeept the Roadian and the upper Dorashamian, either only long-ranging shallow-water eonodonts are present or the range of shallow-water speeies is not yet well established.

Reeently, it has been attempted to define all Permian stages as well as the base and the top of the Permian with eonodonts. For the Guadalupian and Lopingian Series this may be problematieal. Partieularly if the stages are defined with warm-water gondolellids that are, exeept for the base of the Roadian, not yet well eorrelated with eool-water gondolellids or with the shallow-water eonodont sueeessions, the reeognition of the eonodont-defined stages is very diffieult in the Boreal realm, Gondwana and in Tethyan shallow-water or eold bottom-water faunas. A Middle–Upper Permian warm-water gondolellid zonation alone, without serious eonsideration of ammonoids, fusulinids and radiolarians is not suited for definition of eorrelatable Permian stages and sub-stages. At least the eorrelation with the ammonoid and fusulinid zonations as well as with the eool-water eonodont zonation should be established before sueh a definition. If the first appearanee datum (FAD) of *Mesogondolella aserrata* and *M. postserrata* does not eoineide with a ehange either in the eool-water gondolellid fauna, and/or ammonoid fauna and/or in fusulinid faunas, these FAD are diffieult to use for definition of the base of the Wordian and Capitanian stages respeetively. For the FAD of *M. aserrata* this is rather probable and, moreover, this FAD lies distinetly above the FAD of *Waagenoceras*, the traditional base of the Wordian.

BOUNDARIES OF THE PERMIAN

The base of the Permian (base of the Asselian Stage) is the only offieially approved stratigraphie boundary of the Permian System (Davydov et al. 1995, 1996; Chernykh et al. 1997; Chernykh & Ritter 1997). It was defined by the first appear-anee datum (FAD) of *Streptognathodus isolatus* Chernykh et al. (forerunner: *S. wabaunsensis* Gunnell) in the Aidaralash seetion (southern Cis-Urals). This boundary eoineides with the base of the *S. invaginatus–S. fuchengensis* Zone (Kozur 1996a) and lies in Aidaralash 6.3 m below the traditional fusulinaeean boundary, the base of the *Sphaeroschwagerina vulgaris–S. fusiformis* Zone marked in Aidaralash by the FAD of *Sphaeroschwagerina*, and 26.8 m below the traditional ammonoid boundary (*Svetlanoceras–Juresanites* genozone), marked in Aidaralash by the first appearanee of *Svetlanoceras primore* and *Prostacheoceras principale*. The eorrelation with the low latitude ammonoid faunas is not well established, but it lies below the FAD of *Properrinites*, the traditional Tethyan Carbon-iferous–Permian boundary.

The eorrelation with eontinental beds is diffieult beeause the Carboniferous–Permian boundary is not an event boundary. Aeeording to Kozur (1989) it eorresponds to the base of the *Lioestheria paupera* eonehostraean Zone (and eorrelated other faunal

zones; Kozur 1990b: 20, table 6; Kozur 1993e: table 2), somewhat above the base of the *Autunia conferta* floral assemblage zone. A similar correlation was presented by Schneider et al. (1995).

The definition of the Permian–Triassic boundary (PTB) with the FAD of *Hindeodus parvus* (Kozur & Pjatakova) within the phylomorphogenetic lineage *H. typicalis* (Sweet)–*H. latidentatus praeparvus* Kozur–*H. parvus* is now widely accepted (Yin Hongfu 1985, 1993; Kotlyar et al. 1993; Kozur

1994a, 1995a, 1995b, 1996a, 1996b, 1996c, 1996d, 1997a, 1997b, 1997c. 1997d, in press; Paull & Paull 1994; Wang Cheng-Yuan 1994, 1995; Zhu Xiang-shui et al. 1994; Ding Meihua et al. 1995; Zhang Kexin et al. 1995, 1996; Igo 1996; Kozur et al. 1996; Lai Xulong et al. 1996; Wang Cheng-Yuan et al. 1996; Wignall & Hallam 1996; Wignall et al. 1996; Yin Hongfu et al. 1996a, 1996b; Yin Hongfu & Zhang Kexin 1996; Hallam & Wignall 1997; Zhu Xiangshui & Lin Liansheng 1997).

Stage	Substage	Ammonoid Zone/Subzone		Conodont Zone tethyal (Kozur, 1996a,b, 1997a,d)	
		Tethyan[1]	Boreal[2]		
S C Y T H I A N — Brahmanian ("Induan")	Gandarian (Dienerian)	Prionolobus rotundatus	Kingites ? korostelevi	Neospathodus dieneri	
			Vavilovites turgidus		
		Pleurogyr. planidorsatus	Vavilovites sverdrupi	Sweetospathodus kummeli	
			Proptychites candidus	Clarkina postcarinata	
	Gangetian	Ophiceras tibeticum	Bukkenites strigatus	C. carinata	Hindeodus postparvus-H. sosioensis
			Ophiceras commune	Isarcicella isarcica	
		Otoceras woodwardi-Ophiceras bandoi		Hindeodus parvus	
L O P I N G I A N — Dorashamian		Hypophiceras changxingense-Otoceras fissisellatum	Otoceras boreale	H. latidentatus praeparvus-Clarkina meishanensis	
		Rotodiscoceras asiaticum-Pleuronodoceras mapingense	Otoceras concavum	Clarkina changxingensis-Clarkina deflecta-Hindeodus typicalis	
		Paratirolites waageni	?	Clarkina subcarinata-Hindeodus julfensis	
		Shevyrevites shevyrevi			
		Dzhulfites spinosus	regional gap or no ammonoids		
		Iranites transcaucasicus			
		Phisonites triangulus			

Right-margin annotations:
- ▲▲▲▲▲▲... LAD *Tympanicysta*
- 250 my
- *
- ┼┼┼
- LAD fusulinids
- base *L. obsoleta-L. noviaulensis* Zone

Fig. 1. Ammonoid and conodont zonation across the Permian–Triassic boundary (from Kozur, in press). Vertical distances not time-related. [1] Kozur (1993), Krystyn & Orchard (1996) and Kozur (1997a). [2] Tozer (1967) and Gagys & Ermakov (1996). ▬ = original biostratigraphic Permian–Triassic boundary, recognisable only in western Perigondwana. ▲▲▲ = proposed Permian–Triassic boundary, world-wide recognisable in shallow and pelagic marine beds. * = end of the mass occurrences of marine fungi (*Tympanicysta* etc.). ┼┼┼ = main extinction event of the Tethyan shallow warm-water benthos.

The FAD of *H. parvus* nearly coincides with the base of the *Otoceras woodwardi* Zone; it lies only a few centimetres below this boundary. However, the *Otoceras concavum* Zone and most of the *O. boreale* Zone of the Arctic are older than the *O. woodwardi* Zone and the *Hindeodus parvus* Zone (Figs 1, 2). In Greenland, the lower part of the *Otoceras* beds ('*Glyptophiceras* Beds') was assigned to the *O. concavum* Zone (Tozer 1967), but Dagys (1994) demonstrated that it belongs to the lower *O. boreale* Zone, whereas the *Metophiceras subdemissum* Zone belongs to the upper *O. boreale* Zone s.l. A restudy of the conodont material published by Sweet (1976) from the *Otoceras*-bearing beds of Greenland has shown the following conodont distribution: (1) The lowermost *Otoceras* beds contain *Clarkina deflecta* Wang & Wang, *Clarkina* sp. nov. A of the *C. carinata* group

		Himalaya	Meishan	Selong	South. Alps	Greenland	Arctic Canada	Germanic Basin
	Gand.	Prionolobus rotundatus			Siusi Member	U. breviformis Cornia germari		Bernburg Formation
	Brar	Pleurogyr. planidorsatus	Yinkeng Formation	Kangshare Formation: Pleurogyronites planidorsatus			V. sverdrupi	
							P. candidus	
SCYTHIAN / INDUAN	Ghangetian	Ophiceras tibeticum	Boundary Bed 3	Ophiceras tibeticum	Andraz Horizon (evaporitic)	P. rosenkrantzi / W. decipiens	B. strigatus	Nordhausen: red, above limnic, below mostly sabkha / Sandy Claystone Member
						Oph. commune	Oph. commune	variegated
		O. woodwardi	Boundary Bed 2 (d / c / a+b)	O. woodwardi	Mazzin Member	T. pascoei		
				O. "latilobatum"		M. subdemissum- H. martini	Otoceras boreale	Form. Clayey Sandstone Member
	Dorashamian		Boundary Bed 1 250 my→		Tesero Oolite	Hypoph. triviale		
LOPINGIAN			Changxing Limestone		Bellerophon Limestone Formation		O. concavum ↓ ?	Bröckel= schiefer s.s. / 7 / 6 / 5 / 4
	Dzhulfian	Kuling Formation	Longtang Formation			Schuchert Dal Formation	spiculitic chert	Zechstein / 3 / 2 / 1

Fig. 2. Correlation chart of some important marine and continental successions from Kozur (in press). Detailed only around the PTB. Vertical scale not thickness- or time-related! The upper Capitanian part is only shown for the continental successions (Fig. 2b). After Baud et al. (1996), Cheng Zengwu et al. (1989), Jin Yugan et al. (1996), Kozur (1989, 1994b, 1996), Kozur & Seidel (1983), Kozur et al. (1996), Krystyn & Orchard (1996), Lozovsky (1993), Lucas (1993), Perch-Nielsen et al. (1974), Rasmussen et al. (1990), Renne (1995), Sadovnikov & Orlova (1993), Teichert & Kummel (1976), Tozer (1967), Tuzhikova (1985), Xia Fengsheng & Zhang Bingao (1992) and

and *Hindeodus typicalis*. (2) The largest part of the *Otoceras* beds contains a low diversity, but rich conodont fauna with *Clarkina* sp. nov. A and *H. typicalis*, in the upper *Otoceras*-bearing beds additionally increasing amounts of *H. latidentatus praeparvus*. (3) Very primitive *H. parvus* occurs in an interval that has not yielded neither *Otoceras* nor the guideforms of the *Ophiceras commune* Zone. This level contains last small *Hypophiceras*,

Tompophiceras gracile (Spath) and *T. pascoei* (Spath). The latter two species are guideforms of the *Tompophiceras pascoei* Zone between the *O. boreale* Zone s.s. and the *O. commune* Zone. According to Dagys & Ermakov (1994) this zone corresponds to the uppermost *O. boreale* Zone s.l. of Greenland and Svalbard. The FAD of very primitive *H. parvus* in the uppermost *O. boreale* Zone s.l. of Greenland indicates that the Peri-
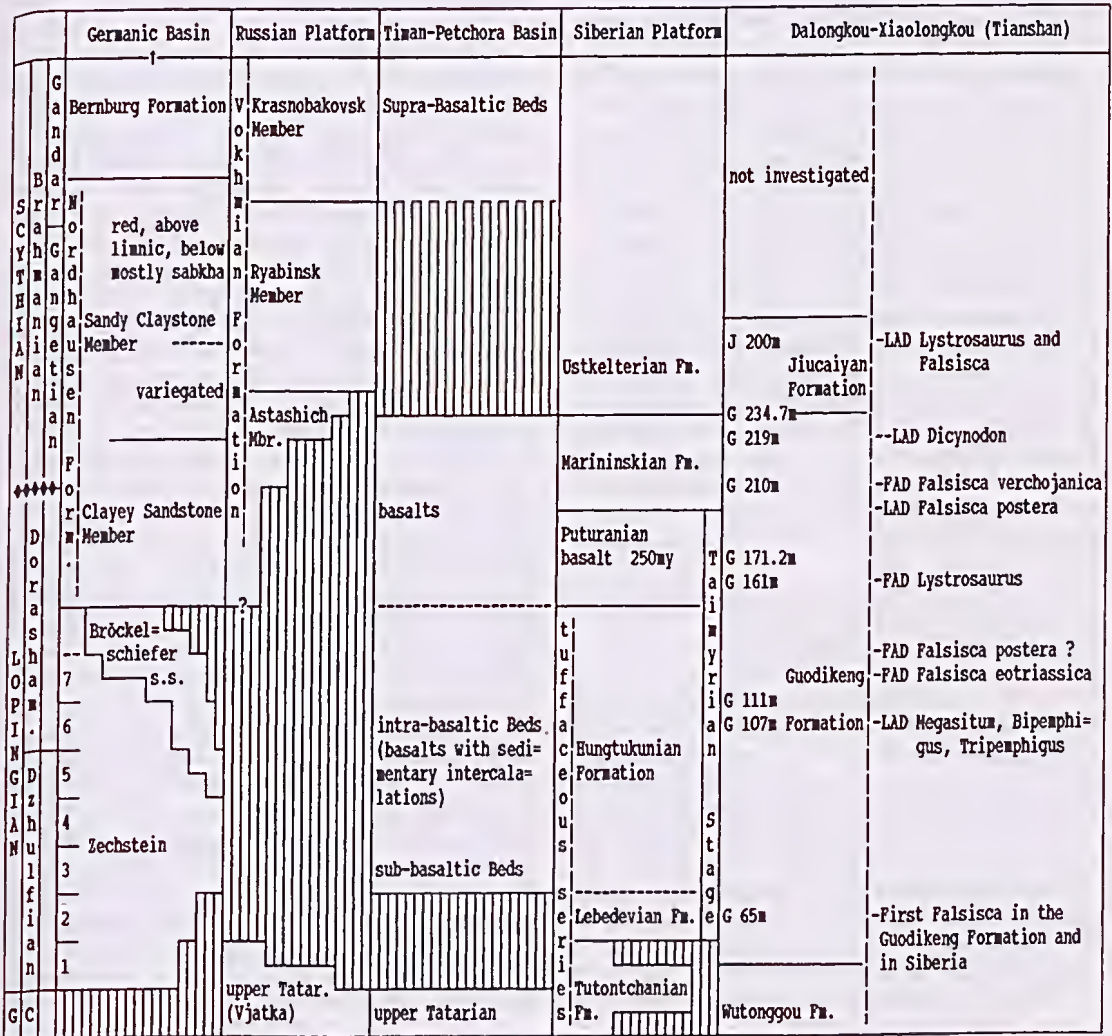
Yin et al. (1996). *Fig. 2a*: Marine successions and Germanie Basin (mixed marine-continental). *Fig. 2b*: Continental successions and Germanic Basin. ♦♦♦ = used P/T boundary (FAD of *Hindeodus parvus* in marine beds). G = uppermost Guadalupian Series (only on Fig. 2b). C = Upper Capitanian Stage (only on Fig. 2b). G 111m etc. = 111 m above the base of the Guodikeng Formation in the Dalongkou section etc. Measurement after Lucas (1996), during a joint project sponsored by the NGS, USA. J 200m = 200 m above the base of the Jiucaiyan Formation in the Xiaolongkou section.

gondwanan *O. woodwardi* Zone (with advanced *H. parvus*) is younger than the *O. boreale* Zone of the Boreal realm. As the base of the Triassic is defined originally by the FAD of *O. woodwardi*, the Boreal *Otoceras* faunas belong by this definition to the Permian as pointed out by Kozur (1994a).

Krystyn & Orchard (1996) have shown that *H. parvus* begins at the Perigondwana margin a few centimetres below the *O. woodwardi* Zone in a level with an *Otoceras* of the *O. boreale* group, *O. latilobatum*, which is a junior synonym of *O. fissisellatum*. Krystyn in Krystyn & Orchard (1996) pointed out that *O. woodwardi* is more advanced than *O. boreale*, and that the *O. woodwardi* Zone follows in the Selong section of Tibet in stratigraphic succession above a fauna with *Otoceras* of the *O. boreale* group. By this, it was shown for the first time by ammonoids that the Perigondwanan *O. woodwardi* Zone is younger than the Boreal *Otoceras* faunas, as before proven by conodonts (see above). The results of Krystyn & Orchard (1996) solved the contradiction between the conodont and ammonoid correlations. Whereas the conodonts have shown that the Perigondwanan *O. woodwardi* Zone, the oldest ammonoid zone of the Triassic, is younger than the Boreal *O. concavum* Zone, and at least the largest part of the *O. boreale* Zone (Kozur 1994a, 1995a, 1996b, 1997c), all ammonoid workers before Krystyn & Orchard (1996) had correlated the *O. woodwardi* Zone either with the *O. boreale* Zone (e.g. Dagys 1994) or with the *O. concavum* Zone (e.g. Tozer 1967).

The definition of the base of the Triassic with the first appearance of *Hindeodus parvus* has significant advantages over other definitions:

1. There is a clear phylomorphogenetic lineage from *Hindeodus typicalis* through *H. latidentatus praeparvus–H. parvus* to *H. postparvus* Kozur.
2. The first appearance of *H. parvus* is the only event that can be traced throughout the tropical low latitude Tethyan warm-water fauna, the southern middle latitude cool-temperate water faunas of Perigondwana, and the northern high latitude cold-water faunas of the Boreal realm.
3. *Hindeodus excavatus*, *H. typicalis*, *H. latidentatus praeparvus* and *H. parvus* belong to those *Hindeodus* species that occur both in deep-water and shallow-water deposits. As for the most *Hindeodus* species, their occurrences do not so much depend from the water depth, but from the presence and frequency of better adapted conodonts (Kozur 1996b). As adapted shallow-water conodonts, such as *Stepanovites*, *Ellisonia* and *Merrillina*, are mostly rather rare, *H. parvus*

and most other *Hindeodus* species are very common and often dominant in shallow-water deposits. In contrast, gondolellids are better adapted to deep-water conditions than most *Hindeodus* species which are, consequently, rather rare in the gondolellid biofacies. However, there are Permian radiolarites of Panthalassa that contain exclusively *Hindeodus* species, and no gondolellid species is present, and also *H. parvus* occurs in pelagic sediments, where it is dominant or the only conodont species, if gondolellids are absent (Kozur 1996b).

No other fossil with a short range and known phylomorphogenetic connection with its forerunner has such a wide distribution during the earliest Triassic. During the *H. parvus* Zone, gondolellid conodonts are missing in the entire western Tethys, both in shallow-water sediments, where they are missing everywhere, but also in basinal and slope deposits, where they are generally most common. This phenomenon can be explained by the extinction of all latest Permian warm-water gondolellids of the *Clarkina subcarinata* group at the PTB. The gondolellid conodonts of the overlying *Isarcicella isarcica* Zone belong to *Clarkina carinata* group that is restricted during the uppermost Permian to the high latitude cool and cold-water faunas, migrating into the Tethyan warm-water realm after extinction of all warm-water gondolellids. They reached the western Tethys, however, only at the base of the *Isarcicella isarcica* Zone. In the central Tethys, gondolellid conodonts are missing in the *H. parvus* Zone as well. Thus, gondolellid conodonts are absent in the *H. parvus* Zone in the following areas: Southern Alps (e.g. Staesche 1964; Perri 1991; Perri & Andraghetti 1987; Kozur 1996b), Bükk Mountains of Hungary that are a possible continuation of the Vardar Zone (Kozur 1985, 1991b), Dinarids and Hellenids (Kozur, unpubl. mat.), toe of slope deposits in western Sicily (Gullo & Kozur 1993; Kozur 1995b, 1996b), Karakaya oceanic complex of northwestern Turkey (basinal facies; Kozur, unpubl. mat.), Antalya Nappe in southern Turkey (Kozur, unpubl. mat.), and the Elburs (Hirsch & Süssli 1973). Gondolellids are also missing at least in large parts of the *H. parvus* Zone of Transcaucasia, northwestern Iran and Central Iran (Sweet 1973, Kozur; 1975, Kozur et al. 1975, 1978; Kozur & Pjatakova 1976). Gondolellids are missing in shallow-water deposits of the Circum-Pacific realm, e.g. in Japan, where no pelagic conodont faunas are known from the *H. parvus* Zone (Igo 1996), and in shallow-water deposits of the eastern Tethys, as in SE Sichuan (Wignall & Hallam 1996) and Jiangxi (Zhu Xiang-

shui et al. 1994), both in China. In all these occurrences *H. parvus* is common, in basinal and slope deposits of the western Tethys even the only present conodont species.

During the earliest Triassic *H. parvus* Zone, gondolellids are restricted to pelagic deposits of the eastern Tethys, the eastern Perigondwana shelf, and to the Arctic. In all these occurrences, *H. parvus* is also present. Only in Svalbard (Spitsbergen), a gondolellid fauna is known that has not yielded *Hindeodus* (Dagis & Korchinskaja 1987, 1989), but the exact age of this fauna is unknown. The *Clarkina*, present in this fauna, is not *C. carinata* as determined by Dagis & Korchinskaja (1987, 1989).

Ammonoids have a similar restricted distribution at the base of the Triassic. They are unknown from the *H. parvus* Zone of the basal Triassic in the entire western Tethys, and also missing in basinal and slope deposits. Surprisingly, they are also unknown in the *H. parvus* Zone of Transcaucasia, NW and Central Iran, despite the fact that in these areas they are common in under- and overlying beds. In the Arctic, ammonoids have a wider distribution than conodonts. This is partly caused by the fact that no limestones are present in the basal Triassic of most of the Arctic, and the shales in general have not been investigated for conodonts. In Arctic Canada, where shales have been investigated, conodonts were found (Henderson 1993). However, numerous samples from *Otoceras*-rich shales in NE Siberia (*Otoceras boreale* and surrounding rocks, material Zakharov, Vladivostok), dissolved for conodonts, yielded only in one sample from the lower *O. boreale* Zone of the Setorym River section a few broken specimens of *H. typicalis* and *Clarkina* sp. Thus, most shales of the *Otoceras* faunas in the Arctic (at least in NE Siberia) do not contain conodonts. Seemingly, the water-temperature was mostly below the tolerance boundary for conodonts.

Independently from the later final definition of the PTB, the base of the *H. parvus* Zone is the only reliable correlation horizon near the PTB that can be traced through all marine facies and in all faunal provinces. This is very important because there are, per definition, four different PTB in marine and continental beds that are all situated in different stratigraphical levels, but were mostly equated with each other.

1. The base of the Buntsandstein in the southwestern Germanic Basin is the originally defined base of the Triassic. It is a diachronous boundary within different Dzhulfian and lower Dorashamian levels, as Zechstein equivalents, such

as the Bröckelschiefer, Leberschiefer and Tigersandstein were included in the Buntsandstein of SW Germany (Fig. 2).

2. The base of the *Otoceras woodwardi* Zone as the first palaeontologically defined PTB (Figs 1, 2). This boundary lies only insignificantly, a few centimetres, above the base of the *H. parvus* Zone and can be thus, for the first time, approximately correlated with areas outside the eastern Perigondwana margin, the only area, in which *O. woodwardi* occurs. In most cases, the *O. woodwardi* Zone follows after a gap above Permian sediments of different age (Fig. 2). However, in Selong (Tibet), the *O. woodwardi* Zone follows above equivalents of the uppermost *O. boreale* Zone, and a long gap lies below the beds with *O. fissisellatum* (= *O. latilobatum*) which overly beds with Guadalupian cool-water conodonts.

3. The base of the *Otoceras concavum* Zone in the Arctic is generally equated with the base of the *O. woodwardi* Zone (e.g. Tozer 1967), but it is two ammonoid zones older as now shown by ammonoid evidence (Krystyn & Orchard 1996).

4. The first appearance datum (FAD) of *Lystrosaurus* in continental beds. This boundary is not connected with any distinct change in the continental fauna. Even in the vertebrate fauna this is not a pronounced boundary because the Permian *Dicynodon* continues in a long interval of co-occurrence of *Lystrosaurus* and *Dicynodon*, whereas other Permian vertebrates disappeared earlier.

This boundary lies high above the top of the Tatarian. In the Dalongkou section, *Lystrosaurus* begins 96 m above the FAD of *Falsisca*, a clearly post-Tatarian conchostracan genus that occurs both in the Upper Permian and in the lowermost Triassic. And it lies about 54 m above the disappearance of the typical Permian conchostracan genera *Megasitum*, *Bipemphigus* and *Tripemphigus*. The interval with the joint occurrence of *Lystrosaurus* and *Dicynodon* is characterised by conchostracan faunas with *Falsisca eotriassica* Kozur & Seidel and *F. postera* Kozur & Seidel which also occur in the Germanic Basin. The *F. postera* fauna of the Germanic Basin can be well correlated with the Tesero Oolite of the Southern Alps, in which the last fusulinids, Permian brachiopods and a conodont fauna with *H. latidentatus praeparvus* Kozur and *Stepanovites dobruskinae* Kozur & Pjatakova occur. This is an upper Dorashamian shallow marine fauna (Kozur 1989, 1994b, 1996b).

Thus, the PTB in continental beds is not at the FAD of *Lystrosaurus*, but rather close to the dis-

appearance of the Permian guide form *Dicynodon*. However, in most places, the horizon with *Lystrosaurus* and *Dicynodon* is not present, either because of a gap or because of missing tetrapod record. In most of these areas, the first occurrence of *Lystrosaurus* does not coincide with the FAD of *Lystrosaurus*, but lies within the *Lystrosaurus*-bearing level above the last occurrence of *Dicynodon*. Thus, in most places, the beds with *Lystrosaurus* are really Triassic. However, where the horizon with co-occurrence of *Lystrosaurus* and *Dicynodon* is present, in Dalongkou and in South Africa, it is apparently of Permian age.

SUBDIVISION OF THE PERMIAN SYSTEM

Full agreement was reached in the Permian Subcommission to use the Russian standard of the Cisuralian (Lower Permian) Series: Asselian,

Sakmarian, Artinskian and Kungurian stages. By this, we were able to preserve as many Permian stages from the Russian type area as possible.

However, only the base of the Asselian is fixed as the base of the Permian (see above). The base of the Sakmarian and the base of the Artinskian are not clear. I have tentatively placed the base of the Sakmarian at the base of the *Mesogondolella obliquimarginata–Sweetognathus merrilli* Zone (Fig. 3). This boundary approximately corresponds to the traditional base of the Sakmarian (at the base of the *Pseudofusulina moelleri* fusulinid zone), but in the conodont evolution, it is not a distinct boundary and it has low potential for international correlation. The smooth upper Asselian and Sakmarian *Mesogondolella* of the Cis-Urals are oversplit, and a taxonomically difficult group. Tethyan and North American equivalents of this boundary have not been found.

| Series | Stage | Conodont Zones and Assemblage Zones | | Conodont Standard-Zonation |
		Shallow-water	pelagic	
Guadalupian (pars)	Roadian	Sweetognathus subsymmetricus Neostreptognathodus clinei	Mesogondolella nankingensis	Mesogondolella nankingensis-Sweetognathus subsymmetricus
Lower Permian = Cisuralian	Kungurian	Neostreptogn. sulcoplicatus	Mesogondolella idahoensis	M. idahoensis-N. sulcoplicatus
		Sichuanognathus ? prayi	Mesogondolella zsuzsannae	M. zsuzsannae-S. ? prayi
			Mesogondolella glenisteri-Mesogondolella asiatica	M. glenisteri-S. ? prayi
		Neostreptogn. exsculptus-		M. glenisteri-N. exsculptus
		Neostreptognathodus pnevi	M. shindyensis-M. intermedia	M. intermedia-N. exsculptus-N.pnevi
	Artinskian	Neostrept. postpequopensis-Neostreptogn. ruzhencevi		Mesogondolella bisselli-Neostreptogn. postpequopensis
		S. whitei-M. pequopensis	Mesogondolella bisselli	M. bisselli-N. pequopensis
		S. primus-S. whitei		M. bisselli-S. primus
	Sakmarian	S. primus-Sweetogn. n. sp.	M. bisselli-M. visibilis	M. bisselli-M. visibilis
			M. obliquimarginata	M. obliquimarginata-S. merrilli
		Sweetognathus merrilli	Mesogondolella striata-Streptognathodus barskovi	Streptognathodus barskovi-Sweetognathus merrilli
	Asselian	Wardlawella expansa-Streptognathodus constrictus	Mesogondolella adentata-Streptognathodus constrictus	Streptognathodus constrictus
		Wardlawella expansa-Streptognathodus fuchengensis	Streptognathodus invaginatus-Streptognathodus fuchengensis	Streptognathodus invaginatus-Streptognathodus fuchengensis

Fig. 3. Cisuralian (Early Permian) conodont zonation (after Kozur 1996a, 1997d).

A distinct conodont change occurs in the upper Asselian, at the FAD of *Sweetognathus merrilli* Kozur, the oldest *Sweetognathus* species, that evolved from *Wardlawella expansa* (Perlmutter). However, this boundary lies distinctly below the traditional base of the Sakmarian Stage. On the other hand, this distinct conodont boundary coincides with the base of the *Svetlanoceras strigosum* ammonoid zone that comprises the upper Asselian and lower Sakmarian Tastubian Substage (Kozur 1993a).

In contrast, the base of the upper Sakmarian Sterlitamakian Substage is well defined and correlatable both in pelagic and shallow-water deposits by the FAD of *Mesogondolella bisselli* (Clark & Behnken) and *Sweetognathus primus* Chernykh. It is also a distinct ammonoid boundary (base of the *Sakmarites inflatus* Zone in the northern high latitude faunas and in the Cis-Urals, and base of the *Properrinites boesei* Zone in the low latitude ammonoid faunas), and a distinct radiolarian boundary (base of the *Camptoalatus monopterygius–Patrickella plumata* Zone; Kozur & Mostler 1989; Kozur 1993a).

Virtually no changes occur in the conodont fauna at the traditional base of the Artinskian (base of *Pseudofusulina concavutas* fusulinid zone). This is also the case in most other fossil groups. Even with fusulinids an exact correlation of South Uralian and adjacent Tethyan fusulinid limestones is impossible. On the other hand, close to the base of the Upper Artinskian Baigendzhinian Substage a very distinct and easily correlatable change in conodont faunas can be observed characterised by the final disappearance of all Carboniferous holdovers and above all by the FAD of *Neostreptognathodus pequopensis* Behnken. *Neostreptognathodus* comprises numerous Baigendzhianian and Kungurian guide forms. The ammonoids also show distinct changes in this level, e.g. the FAD of the genus *Perrinites* in the low latitude fauna and distinct changes at the base of the *Neocrimites fredericksi–Propinacoceras ajense* Zone of the Cis-Urals (Ruzhencev 1956; Kozur 1993a). The change of the fusulinid faunas at the base of the *Parafusulina solidissima* are also distinct.

The presently used Sakmarian and Artinskian stages are, according to the conodont evolution, and the evolution of most other fossils, arbitrary units. Their boundaries are not exactly correlatable with Permian deposits outside the Cis-Urals, and even difficult to correlate within the Cis-Uralian fore-deep. On the other hand, Upper Asselian + Tastubian (lower Sakmarian), Sterlitamakian (upper Sakmarian) + Aktastinian (lower Artinskian), and

Baigendzhinian (upper Artinskian) are three well correlatable units according to the conodont evolution. To make the Cisuralian standard workable, considerable changes of the hitherto used definitions of the Sakmarian and Artinskian are necessary.

There is a good agreement to define the base of the Kungurian with the first appearance of *Neostreptognathodus pnevi* Kozur & Movshovich, as proposed by Kozur (1993a, 1995a, 1996a) and Jin Yugan et al. (1997). This boundary lies within the upper part of the traditionally used Baigendzhinian, but the former Artinskian–Kungurian boundary was a diachronous facies boundary that was uncorrelatable with Permian deposits outside the Cis-Uralian fore-deep. By the distinct lowering of the base of the Kungurian to the FAD of *N. pnevi*, the name Kungurian could be preserved despite the fact that a large part of the Kungurian consists of poorly correlatable hypersaline deposits. As the scope of a stage is defined by its lower boundary and by the lower boundary of the overlying stage, the Kungurian belongs to the well-defined stages. However, the subdivision of the Kungurian in correlatable biozones must be done largely outside the Cis-Uralian fore-deep. For facies reasons (often hypersaline beds), the type Kungurian contains only a few stratigraphically important fossils with a range beyond the Cis-Urals. Best suited for elaboration of a workable Kungurian biostratigraphic subdivision is the margin of the Delaware Basin in Texas, where basinal, slope and shallow-water deposits are present, and where the overlying Roadian Stage is defined. A Kungurian conodont zonation, partly elaborated in the Delaware Basin, partly in the *Mesogondolella*-dominated Kungurian deposits of the Sosio Valley (western Sicily, western Tethys), is shown in Fig. 3.

A direct correlation of the base of the Kungurian with the Tethyan scale is not possible because *N. pnevi* is missing in the Tethys, and there is no FAD of another fossil that could be used for direct correlation of the type Kungurian with the Tethys. This is one of the reasons why it is not possible to use the Tethyan scale for the Guadalupian Series. The other reasons are listed later (see below).

The absence of *N. pnevi* in the Tethys and its presence in western North America is well explainable by the palaeogeographic configuration. Although the Tethys was spatially close to the Cis-Uralian fore-deep, the marine connection between both areas was closed during the Kungurian. In that time, the marine connection of the Cis-Uralian fore-deep was only via the Boreal sea, far away from the Tethys. From the Boreal sea, the con-

nection went through Arctic Canada to western Canada and the western USA (e.g. Phosphoria Basin of SE Idaho, NW Utah, NE Nevada and the Nevada miogeosyncline) and finally to the low latitude Delaware Basin in Texas and New Mexico. *N. pnevi* is common in the Phosphoria Basin (Wardlaw 1983; Behnken et al. 1986) and also in Nevada, but very rare in the low latitude Delaware Basin. Nevertheless, in all these areas, the base of the Kungurian can be correlated by the FAD of *N. pnevi*. In western North America, the FAD of *N. pnevi* coincides with the FAD of *N. exsculptus* Igo. This species was first described from Japan (margin of Panthalassa) by Igo (1981). Kozur (1978) had figured this species from SE Pamir (Perigondwana margin of the eastern Tethys), but still assigned to *N. sulcoplicatus* (Hawley, Youngquist & Miller), as subsequently Reimers (1991) did for material from the same area. Kozur (1995a) assigned the forms from the SE Pamir to *N. exsculptus* and, finally, Kozur (1995c) found *N. exsculptus* in the Sosio Valley, western Sicily, proving thus the occurrence of this species in the westernmost Tethys. By these discoveries of *N. pnevi* and *N. exsculptus*, the base of the Kungurian can be world-wide recognised, in the Boreal realm and in the Cis-Uralian fore-deep by the FAD of *N. pnevi*, in western North America by the contemporaneous FAD of *N. pnevi* and *N. exsculptus*, and in the Circum-Pacific realm, Perigondwana as well as in the Tethys by the contemporaneous FAD of *N. exsculptus*.

The post-Kungurian Permian stages of the Cis-Ural and Russian Platform cannot be used as an international standard, because they have largely continental, hypersaline or extremely shallow marine deposits. They have been applied in many parts of the world, e.g. in Australia, but rather to fill the space between the Kungurian and the Triassic than on the base of a real correlation. Thus, the Tatarian Stage is used as uppermost Permian Stage, but the correlations of the Tatarian with Middle Europe and North America have shown that it corresponds largely to the Capitanian and its upper boundary lies within the lower part of the Lopingian Series. This is also confirmed by the conchostracan distribution in the Dalongkou section in NW China which indicates that the entire Guodikeng Formation (which belongs to a large part undoubtedly to the Upper Permian) is post-Tatarian in age (Fig. 2). The discovery of two distinct conodont associations in the Kazanian of the Russian Platform by Chalimbadja & Silantiev (1997) opens the possibility for an exact correlation of the Kazanian with the international scale, when these forms will be found outside the Russian

Platform. As they are immigrants connected with a shallow marine transgression after continental deposition, they will be surely found also outside the Russian Platform, at least in the Boreal Permian, from where the transgression came. However, some taxonomic changes of conodont material published by Chalimbadja & Silantiev (1997) are necessary (see below).

The Middle Permian Tethyan scale (Kubergandinian, Murgabian and Midian fusulinid ages) cannot be used for the following reasons.

1. There is no possibility to leave the Uralian standard directly to the Tethys. From the base of the Kungurian upward, there is no phylomorphogenetic cline of any fossil group in the Permian type area that can be directly correlated with the Tethys. The last well correlatable event in the Permian type area is the FAD of *N. pnevi* at the revised base of the Kungurian, but this species is absent in the Tethys (see above). If the Uralian standard can be left directly only through the North American standard, then it is logical to use the Guadalupian standard of its type area (Guadalupe Mountains, west Texas), where the stages are defined in permanently accessible, well exposed, very fossiliferous and thermally unaltered type sections.
2. The type areas of the Kubergandinian and Murgabian stages are situated in remote areas in the Pamir Mountains and are hardly accessible or inaccessible for foreigners.
3. The few known conodonts from the Kubergandinian and Murgabian type areas are thermally strongly altered (CAI = 5), a case that otherwise also excludes the application of palaeomagnetic and stable isotope investigations.
4. The type section of the Midian Stage (Kotlyar et al. 1989) consists of very shallow water, partly intratidal sediments, in which even the shallow-water fusulinid index genus *Yabeina* is missing, and neither ammonoids nor pelagic conodonts are present. These beds, and especially the lower boundary of the Midian in its type section, have no good potential for exact correlation.
5. The original Midian (Kotlyar et al. 1989) is a junior synonym of the Abadehian (Taraz 1971) which has a better correlatable type section (Abadeh, central Iran). In a necessarily strongly revised scope (excluding the Lopingian part), the Midian is a junior synonym of the Capitanian (introduced as a substage by Glenister & Furnish 1961, and elevated in the rank of a stage by Furnish 1973).
6. All Tethyan stages are in reality fusulinid ages. They are not exactly correlatable with fusulinid-

free pelagic deposits of the Tethys and outside the Tethys. As Middle Permian (Guadalupian) fusulinids are missing in the entire Boreal realm, and the North American fusulinids are very different from the Tethyan ones (except on accreted terranes along the western coast), not only pelagic, but also shallow-water deposits outside the Tethys cannot be correlated with the Tethyan scale. However, as fusulinid ages, they are useful for the subdivision of Tethyan shallow-water deposits and worth being correlated with the pelagic scale.

Based on a restudy of the conodonts in the Luodian section (China), the base of the Kubergandinian (fusulinids determined by Prof. E. Leven, Moscow) lies close to the FAD of *Mesogondolella saraciniensis* Gullo & Kozur, *Gullodus catalanoi* (Gullo & Kozur) and *Hindeodus gulloides* Kozur & Mostler. None of these species is present in well-dated sections before the Roadian. The FAD of these species is close to the FAD of *M. nankingensis* (Ching) that is used to define the base of the Guadalupian Series (base of the Roadian Stage). *H. gulloides* is restricted to the Roadian in its type section.

The scope of the Murgabian in pelagic Tethyan sediments is not yet known. This fusulinid age was equated always with *Waagenoceras*-bearing beds (without *Timorites*), and in palaeogeographic reconstructions the occurrence of pelagic Murgabian is based on the occurrence of *Waagenoceras* (Baud et al. 1993). However, Kozur & Davydov (1996) have demonstrated that this correlation is unsubstantiated. They investigated the conodont and fusulinid fauna from the type locality (Rupe de Passo di Burgio block in the Sosio Valley, western Sicily) and type stratum of *Waagenoceras mojsisovici*, the type species of the Wordian ammonoid genus *Waagenoceras*. This small block contains one of the richest Wordian ammonoid faunas in the world and contains 23 ammonoid species (the species list is given in Kozur & Davydov 1996). Such typical Wordian ammonoid faunas were assigned to the Murgabian in the Tethyan scale, and on this assignment the correlation of the Wordian with the Murgabian was based. The rich conodont fauna with *Gullodus catalanoi* (Gullo & Kozur), *Mesogondolella siciliensis* (Kozur), *Stepanovites festivus* (Bender & Stoppel) and *Sweetocristatus galeatus* (Bender & Stoppel) confirms the Wordian age (Gullo & Kozur 1992). However, the fusulinids clearly indicated a lower Midian fusulinid age. In the Cache Creek terrane (Canada) the co-occurrence of Wordian ammonoids with lower Midian fusulinids was also

observed. On the other hand, in the Luodian section, Murgabian fusulinids occur together with the Wordian *M. siciliensis* fauna. Thus, the 'Murgabian' *Waagenoceras* and *Mesogondolella siciliensis* faunas correspond only partly to the Murgabian, partly they belong to the lower Midian fusulinid age. Apparently, the base of the Midian does not correspond to any pronounced change in the pelagic faunas.

Whereas the pelagic Tethyan faunas can be well correlated by ammonoids with the stages of the Guadalupian Series, the Murgabian and Midian Tethyan 'stages' (fusulinid ages) cannot be exactly correlated with Tethyan and other pelagic deposits. However, this advantage of the Wordian Stage will be lost, if the traditional boundary, the FAD of the ammonoid *Waagenoceras* is changed to the FAD of the conodont *Mesogondolella aserrata* (Clark & Behnken) as proposed by Lambert (1996) and Wardlaw (1996). This boundary is excellently documented in the Delaware Basin and also in similar intra-platform basins in South China. However, the first appearance of *M. aserrata* does not coincide with the first appearance of *Waagenoceras*, the traditional base of the Wordian at the base of the Willis Ranch Member of the Word Formation of the Glass Mountains (with the type section of the Wordian Stage) and within the Pipeline Shale at the base of the Brushy Canyon Formation of the Guadalupe Mountains. In the Glass Mountains, *M. aserrata* begins at the base of a siltstone between the Willis Ranch and Apple Ranch members of the Word Formation (Wardlaw 1996), and within the Getaway Limestone Member at the base of the Cherry Canyon Formation of the Guadalupe Mountains (Rohr 1996; for correlation of the lithostratigraphic subdivisions in the Guadalupian Series of Guadalupe Mountains and Glass Mountains see Table 1 and Kozur & Mostler 1995).

To use the FAD of *M. aserrata* as base of the Wordian instead of the traditional boundary, the FAD of *Waagenoceras*, may cause serious problems for the correlation with the Tethys. The serrated *Mesogondolella*, by some authors (e.g. Mei Shilong & Wardlaw 1996; Yin Yugan et al. 1997) discriminated as *Jinogondolella* (nomen nudum), are restricted to pelagic warm-water faunas. These are low latitude faunas either from shallow pelagic deposits above 200 m water depth or from deep-water deposits in intra-platform basins, like in the Delaware Basin and intra-platform basins in South China. These basins have during the Guadalupian in a hot and relatively dry climate the circulation model of the present-day Mediterranean Sea. That means, even in great water depth, they have warm water.

In cold-water faunas, including open sea deposits from low latitude areas with cold oceanic bottom currents, serrated gondolellids are missing and replaced by smooth *Mesogondolella* of the *M. saraciniensis–M. siciliensis–M.* sp. nov. and *M. phosphoriensis–M. rosenkrantzi* lineages (Fig. 4). Thus, not only high latitude Perigondwana and Boreal faunas have exclusively these smooth *Mesogondolella*, but also the majority of the Tethyan faunas (all known central and western Tethyan pelagic Guadalupian conodont faunas from Oman to Sicily, open-sea eastern Tethyan faunas).

The correlation of these two different gondolellid faunas is not easy and not yet solved for much of the Guadalupian. The proposed base of the Guadalupian (base of the Roadian Stage, FAD of *M. nankingensis*) coincides with the FAD of *M. saraciniensis* Gullo & Kozur and of *M. gracilis* (Clark & Ethington). In slope to shallow-water deposits at this boundary *G. catalanoi, H. gulloides* and perhaps also *Sweetognathus subsymmetricus* Wang, Ritter & Clark appeared.

The exact level of the FAD of *M. phosphoriensis* (Yongquist, Hawley & Miller) and *M. siciliensis* (Kozur) is not yet known, but it distinctly predates the FAD of *M. aserrata*, and for *M. siciliensis* it is distinctly higher than the base of the Roadian, where the FAD of *M. saraciniensis* (forerunner of *M. siciliensis*) is situated. In the entire Tethys, *M. phosphoriensis* begins before *M. siciliensis*. However, the lower *M. phosphoriensis* fauna above the level with *M. saraciniensis* yielded neither in the western Tethys (western Sicily) nor in the eastern Tethys (e.g. Luodian section in southwest China) *M. saraciniensis* or *M. siciliensis*. On the other hand, the *M. saraciniensis* fauna yielded neither *M. idahoensis* nor *M. phosphoriensis*. Thus, neither the FAD of *M. phosphoriensis* nor the FAD of *M. siciliensis* can be fixed within a section. In Luodian, *M. phosphoriensis* begins at the base of bed 25b, about 27 m above the FAD of *M. saraciniensis*. About 10 m higher, in the middle part of bed 25b, *M. siciliensis* begins. In the same level, transitional forms between *M. idahoensis*

Slope of Guadalupe Mts. and adjacent Delaware Basin			Glass Mountains		
Group	Formation	Member	Formation	Member	Stage
Delaware Mountain	Bell Canyon	Reef Trail	Altuda		?--Dzhulfian ?-----------
		Lamar Limestone McCombs Limestone Rader Limestone Pinery Limestone Hegler Limestone			Capitanian
	Cherry Canyon	Manzanita Limestone South Wells Limestone	Vidrio		Wordian
		Getaway Limestone	Word	Appel Ranch Willis Ranch China Tank	
	Brushy Canyon	undifferentiated			
	Cutoff	Willams Ranch El Centro Shumard Canyon	Road Canyon		Roadian
	Bone Spring Limestone	undifferentiated	Cathedral Mountains		Kungurian

Table 1. Lithostratigraphic nomenclature for the Delaware Basin (slightly modified after Kozur & Mostler 1995).

and *M. nankingensis* are also present, which are probably reworked as *M. phosphoriensis* occurs nowhere in the world before *M. nankingensis* that evolved from advanced *M. idahoensis*, transitional to *M. phosphoriensis*. Thus, the FAD of *M. phosphoriensis* should coincide with the FAD of *M. nankingensis* or slightly postdate it.

Until the lower part of bed 26b of the Luodian section, *M. phosphoriensis* and *M. siciliensis* co-occur, then only *M. siciliensis* occurs. Thus, the interval of co-occurrence of the two species is about 25 m in the Luodian section. All investigated Tethyan open-sea *Waagenoceras* faunas have yielded exclusively *M. siciliensis* among

T R I A S .	Series	Stage	Conodont Zones and Assemblage Zones				Conodont Standard Zonation		
			Shallow-water	pelagic					
	Early Triassic = Scythian	Brahmanian ("Induan")	Isarcicella isarcica	Clarkina carinata			Isarcicella isarcica		
			Hindeodus parvus			C. tulongensis	Hindeodus parvus		
		Dorashamian	Hindeodus changxingensis- H. latidentatus praeparvus	Clarkina meishanensis			H. lat. praeparvus- C. meishanensis	H. lat. praep.- C. tulongensis	
P			Hindeodus typicalis- Iranognathus sosioensis	C. deflecta- C. changxin= gensis	C. xiangxiensis C. postwangi	C. n. sp.	C. changxingensis- C. deflecta- H. typicalis	H. typicalis- Clarkina n. sp.	
				Clarkina subcarinata		---	C. subcarinata-H. julfensis	-------	
	Upper Permian = Lopingian		Hindeodus julfensis	Clarkina mediconstricta			Clarkina mediconstricta		
E				Clarkina orientalis			Clarkina orientalis		
R		Dzhulfian s. stricto		Clarkina transcaucasica			Clarkina transcaucasica		
M			Iranognathus tarazi- I. unicostatus	Clarkina leveni		M. b r i t a n n i c a	Clarkina leveni	Merrillina divergens- Mesogondo= lella britannica	
I		? new stage or lower Dzhulfian sensu lato	Iranognathus n. sp.	Clarkina niuzhuangensis			Clarkina niuzhuangensis		
				Clarkina postbitteri			Clarkina postbitteri		
		disputed		Clarkina altudaensis-C. crofti			Clarkina altudaensis		
A	Middle Permian = Guadalupian	Capitanian	Hindeodus altudaensis	Mesogondolella shannoni		M. r o.	Mesogondolella shannoni	M. rosen= krantzi-	
				M. postserrata	Mesog. n. sp.		M. postserrata		
N		Wordian	Gullodus sicilianus	M. aserrata	Mesogondolella siciliensis	M. p.	Mesogondolella aserrata	Mes. siciliens.	
		Roadian	S. subsymmetricus	M. nankingensis	M. siciliensis- M. phosphoriensis		Mesogondolella nankingensis- Sweetognathus subsymmetricus	M. sicil.- M. phosph.	
			Neostreptognathodus clinei		M. gracilis- M. saraciniensis			M. grac.- M. sarac.	

Fig. 4. Guadalupian to basal Triassic conodont zonation (slightly modified after Kozur 1995a, 1996a, 1997d). C. n. sp. = *Clarkina* n. sp. of the *C. carinata* group, only present in high latitudes. M. p. = *Merrillina praedivergens*. M. ro. = *Mesogondolella rosenkrantzi*.

the gondolellid conodonts. Therefore, the FAD of *M. phosphoriensis* is within the Roadian. *M. siciliensis* is the most characteristic Wordian species of the smooth *Mesogondolella*, and very common in the entire Tethyan Wordian, but its FAD is within the Roadian.

At the FAD of *M. aserrata* no change in the smooth *Mesogondolella* faunas can be observed. Fusulinids and radiolarians show also no changes in this level. As the FAD of *Waagenoceras* distinctly predates the FAD of *M. aserrata* (see above), the base of the Wordian cannot be correlated with the open sea Tethyan successions, if the FAD of *M. aserrata* is used for definition of the Wordian. For this reason, the traditional base of the Wordian at the FAD of *Waagenoceras* is preferred.

The FAD of *M. postserrata* may coincide with the FAD of a new smooth *Mesogondolella* species in the *M. saraciniensis–M. siciliensis–M.* sp. nov. lineage. This new *Mesogondolella* was found in several Tethyan successions above Wordian faunas with *Waagenoceras* and *M. siciliensis*. It occurs also in Perigondwana faunas. Therefore, the definition of the base of the Capitanian with the FAD of *M. postserrata* (Lambert 1996; Rohr 1996; Wardlaw 1996) may be a good boundary, recognisable both in warm-water intra-platform basin faunas and in open sea Tethyan faunas (with cold bottom-water) as well as in Perigondwana faunas. However, the exact coincidence of the FAD of *M. postserrata* and of *Mesogondolella* sp. nov. must be still proven. In any case, this boundary lies inside the Midian fusulinid age.

The problem with the conodont definition of the Wordian shows that a Permian scale, based only on FAD of conodonts will not solve the problems of the Permian stratigraphy. A serious consideration at least of the ammonoids, fusulinids and radiolarians is necessary.

In some areas, smooth and serrated *Mesogondolella* occur together. Mostly they follow each other. One of these areas is the Phosphoria Basin. Other areas are slope deposits of the eastern and central Tethys, in which generally smooth *Mesogondolella* dominates, but from the shallow, warm-water shelf sometimes serrated *Mesogondolella* are transported (or reworked!) into the deeper, cooler water. These areas seem to be suited for correlations of the zonations of the smooth and serrated *Mesogondolella*. However, this is not so easy. If in middle latitudes the water temperature cools down or upwelling of cooler bottom-water begins, then the smooth *Mesogondolella* suddenly replaces the serrated ones and vice versa, if the water temperature rises. This can be misinterpreted as the first or last appearance datum (FAD or LAD)

of a species. The same can happen, if serrated *Mesogondolella* are washed into the toe of a slope with an autochthonous smooth *Mesogondolella* fauna. As slopes are in general geologically unstable areas, often reworking from the shallower, warm-water part of the slope into the deeper, cold-water part of the slope occurs. Both cases may lead to very big mistakes in the correlation as in the Luodian section (Wang Yu-yin et al. 1994). The first *Mesogondolella nankingensis* is there reported from bed 46, where fusulinids of the upper Murgabian or lowermost Midian fusulinid age occur. This level was taken as the base of the Roadian. In consequence of these data, Jin Yu-gan et al. (1994) assigned Tethyan fusulinid faunas with *Neoschwagerina simplex* to the Cathedralian (Kungurian). Restudy of the conodonts has shown that already more than 253 m deeper, in the middle part of bed 22, a typical Roadian conodont fauna with *Gullodus catalanoi* (Gullo & Kozur), *Hindeodus gulloides* Kozur & Mostler, and *M. saraciniensis* occurs. According to a written communication of Prof. E. Leven, Moscow, this level corresponds to the lowermost Kubergandinian. *G. catalanoi* occurs in the Roadian and Wordian of Sicily (Kozur 1995a), *H. gulloides* is known from the type Roadian in the Glass Mountains (Kozur & Mostler 1995), and *M. saraciniensis* is restricted to the lower or lowermost Roadian of western Sicily (Gullo & Kozur 1992; Kozur 1996a). Thus, the conodont fauna of the middle part of bed 22 of the Luodian sections belongs to the lower or lowermost Roadian. This is insofar important as it indicates that the base of the Roadian coincides with the base of the Kubergandinian. Apparently influenced by the assumed Early Permian age of this level, the gondolellid conodonts of this sample were determined as *M. gujioensis* Igo and *M. intermedia* Igo in Wang Yu-yin et al. (1994). These species were not found in my material and also not in the restudied material of Wang Zhi-hao, Nanjing. Wang Zhi-hao (1994) determined *M. parasiciliensis* Wang Zhi-hao, 1994 from this level which is a junior synonym of *M. saraciniensis* Gullo & Kozur, 1992.

About 27 m higher, at the base of bed 25b, *M. phosphoriensis* appears, and about 10 m higher, within bed 25b, *M. siciliensis* appears. According to a written communication of Prof. E. Leven, Moscow, this bed contains lower Kubergandinian fusulinids. In Wang Yu-yin et al. (1994), the gondolellid conodonts were erroneously determined as *M. idahoensis* (Youngquist, Hawley & Miller), *M. gujioensis*, *M.* cf. *zsuzsannae* Kozur and *M. bisselli* (Clark & Behnken), whereas Wang Zhi-hao (1994) determined from this level

M. idahoensis (in reality *M. phosphoriensis*), *M. gujioensis* (probably a new species) and *M. cf. siciliensis* (= typical *M. siciliensis*).

Transitional forms between *M. nankingensis* and *M. aserrata* and the latter species were reported by Wang Yu-yin et al. (1994) from beds 53 and 54, above and together with a fusulinid fauna that contains *Yabeina* of undoubtedly Capitanian age. Also these gondolellids must be reworked or the determinations are wrong. As mentioned above, in our material transitional forms between *M. idahoensis* and *M. nankingensis* were found in the middle part of bed 25b, but even in this level within the Roadian they seem to be reworked (see above).

Problematic is the lower boundary and sub-division of the Upper Permian (Lopingian) Series. *Clarkina postbitteri* Mei & Wardlaw, the first occurrence of which was used for the definition of the Lopingian lower boundary (Jin Yu-gan et al. 1994; Mei Shilong et al 1994a, 1994b, 1994c; Sheng Jin-zhang & Jin Yu-gan 1994), is probably an immigrant in the Tethys because its forerunner *C. crofti* Kozur & Lucas has not been found outside Texas. The former view that *Clarkina postbitteri* evolved from *Mesogondolella granti* cannot be supported as both species are very different from each other and the *Clarkina postbitteri* fauna follows abruptly above the *Mesogondolella granti* fauna without an interval of overlapping or transitional forms. In the contrast, the youngest *C. crofti* fauna of North America contains tran-sitional forms between *C. crofti* and *C. postbitteri* and Wardlaw (1996 and pers. comm.) found in this fauna also the first, very primitive *C. postbitteri*.

It is dangerous to use the first occurrence of an immigrant species for definition of a series and stage boundary, particularly, if the forerunner is not present in this area. In South China, *C. postbitteri* begins with advanced forms dis-tinctly above the LAD of *C. altudaensis* Kozur. In Texas, very primitive *C. postbitteri*, transitional to *C. crofti*, occurs together with *C. altudaensis* only a little above the FAD of this species. Thus, the FAD of *C. postbitteri* is found in West Texas, whereas the first occurrence of *C. postbitteri* in South China lies clearly above the FAD of this species. Moreover, the occurrence of *C. altudaensis*, *C. crofti* and *C. postbitteri* are facies-related. *C. altudaensis* is a shallow pelagic form. It occurs in the uppermost Altuda Formation of the margin of the Delaware Basin in the Glass Mountains. There, it evolved from the serrated *M. shannoni* Wardlaw (Kozur 1992a, 1992b, 1992c; Wardlaw 1996). *C. crofti* occurs only in the uppermost centimetres of the Altuda formation in a level

with mass occurrences of radiolarians, whereas below this level radiolarians are rare. This level indicates a deepening. *C. crofti* migrated to the Glass Mountains with advanced forms that are partly transitional to *C. postbitteri*, and primitive specimens of the latter species were found by Wardlaw (1996) in this level. In the same level, the Tethyan *C. lanceolata* (Ding) immigrated to the Delaware Basin (Kozur 1995a). This species was assigned erroneously to *C. subcarinata* (Sweet) by Kozur (1992a, 1992b, 1992c). In the basinal Lamar Limestone and the basinal development of the Reef Trail Member (Wilde 1996) of the uppermost Bell Canyon Formation, *C. altudaensis* is missing. In the uppermost 5 cm of the Lamar Limestone, the *M. shannoni* fauna is suddenly replaced by a *C. crofti* fauna without any *Meso-gondolella*. Immediately below, the first transition forms between *M. shannoni* and *C. altudaensis* occur, but the latter species is not present. Obviously, the level of the appearance of *C. crofti* in the basinal facies corresponds to the base of the *C. altudaensis* Zone in the upper slope deposits of the upper Altuda Formation in the Glass Mountains. Such a correlation is also indicated by fusulinids (Wilde 1996). *Clarkina crofti* is also common throughout the entire basinal development of the Reef Trail Member.

Thus, obviously, the *C. crofti* fauna and the *C. altudaensis* Zone of the Delaware Basin are contemporaneous, with *C. crofti* occupying the basinal facies and *C. altudaensis* the upper slope facies. Exceptionally, both species occur together, if the water depth in the upper slope facies increased (uppermost Altuda Formation). As the uppermost Altuda Formation contains also the first primitive *C. postbitteri*, the upper *C. altudaensis* Zone and the lower *C. postbitteri* Zone overlap each other in the Delaware Basin. The view of Jin Yugan et al. (1993) and Sheng Jin-zhang & Jin Yu-gan (1994) that two Capitanian conodont zones follow above the *C. altudaensis* Zone, is therefore unsubstantiated.

The only phylomorphogenetic cline in conodont lineages close to the Guadalupian–Lopingian boundary that can be observed both in North America and in the Tethys, is the development of *C. altudaensis* from *M. shannoni*. As the data published by Wardlaw (1996) show, the base of the *C. altudaensis* Zone lies only a little below the FAD of *C. postbitteri* in the uppermost Altuda Formation of the Glass Mountains. The base of the *C. altudaensis* Zone and the contemporaneous first occurrence of *C. crofti* in the upper centimetres of the Lamar Limestone is accompanied by a distinct change in the radiolarian fauna (Kozur

1992c), indicated by the FAD of *Follicucullus ventricosus* Ormiston & Babcock and *Ishigaconus sholasticus* (Ormiston & Babcock). Both species are typical Lopingian radiolarian taxa distributed from western North America through Japan and China until the westernmost Tethys (Kozur 1993b). For this reason, the base of the *C. altudaensis* was proposed as the base of the Lopingian Series by Kozur (1992c, 1993a). Wilde (1996) came to the same level for the Guadalupian–Lopingian boundary by evaluation of the fusulinid faunas. He recognised that *Paraboultonia* and *Lanschichites* are essentially restricted to post-Lamar Beds and to lateral equivalents in the Apache Mountains (Upper Bell Canyon Formation), and Glass Mountains (Upper Altuda Formation). He pointed out that on this base, the Guadalupian–Dzhulfian boundary might be indicated near the top of the Lamar. His proposal for the Guadalupian–Lopingian boundary on the basis of the shallow-water fauna perfectly coincides with the sharp change in the pelagic fauna in the uppermost 5 cm of the Lamar Limestone.

The recognition of the Tethyan Lopingian base within the Boreal realm is very difficult. Ammonoids are very rare in the lower Lopingian of the Arctic and fusulinids are missing in the Guadalupian and Lopingian of the Boreal faunal realm. Thus, only the conodonts may be used for definition of the base of the Lopingian in the Boreal realm, but lower Lopingian conodonts are only known from Greenland. However, the gondolellid conodonts of the Capitanian (and lowermost Lopingian) are represented mainly by *Mesogondolella rosenkrantzi* (Bender & Stoppel) that begins within the Wordian. The Wordian forms may be separated as an independent subspecies, but there is not much hope to separate the Capitanian and lowermost Lopingian *M. rosenkrantzi* in different taxa (even not in subspecies or morphotype level). An important Dzhulfian guide form of non-tropical conodont faunas is *M. britannica* sp. nov. that occurs in the lower Dzhulfian of the European Zechstein and in the Dzhulfian up to the *Clarkina leveni* Zone in Transcaucasia, Iran and in Perigondwana. The FAD of this species lies probably near to the base of the *C. altudaensis* Zone. Also *Merrillina divergens* and *M. vistulensis* emend. are important Dzhulfian species that may be suited for the correlation of the Boreal and Tethyan faunas. There are, however, considerable taxonomic problems in the differentation of *Merrillina* species (Kozur, in prep.).

The well defined base of the Dzhulfian s.s. (base of the *C. leveni* Zone) lies considerably above the top of the Capitanian leaving an interval with three conodont zones between the top of the Capitanian and the base of the Dzhulfian s.s. (*C. altudaensis*, *C. postbitteri* and *C. dukouensis* zones), or two conodont zones, if the *C. altudaensis* Zone is assigned to the uppermost Capitanian. The Wuchiapingian comprises also this interval but this stage name has no priority and its lower boundary is not yet well defined. Perhaps a new stage should be introduced for this interval.

The base of the Dorashamian (or Changxingian) is well defined by the first appearance of *Clarkina subcarinata*. However, in cool-water faunas, even in cold bottom-water faunas of the Tethys, *C. subcarinata* is not present and replaced by cold-water forms. Also in this case the correlation between the warm-water and cold-water faunas is not yet well established.

SYSTEMATIC PALAEONTOLOGY

A new *Mesogondolella* species, *M. britannica* sp. nov. is described in this section and its relationships within the *Mesogondolella phosphoriensis* lineage are discussed.

Genus Mesogondolella Kozur, 1990a

Type species. Gondolella bisselli Clark & Behnken, 1971.

Mesogondolella britannica sp. nov.

(Figs 5–7)

1986   *Neogondolella* aff. *idahoensis* (Youngquist, Hawley & Miller 1951)—Swift & Aldridge, pp. 231–232, pl. 7.1, figs 10–14.
1995   *Mesogondolella phosphoriensis* (Youngquist, Hawley & Miller)—Swift, pp. 39–43, pl. 3, figs 1–13.
1995   ?*Mesogondolella phosphoriensis* (Youngquist, Hawley & Miller)—Swift, pp. 43–45, pl. 3, figs 14–16; pl. 4, figs 1–9.
1995   *Xaniognathus abstractus* (Clark & Ethington)— Swift, pp. 46–47, pl. 4, figs 10, 11.
1995   *Xaniognathus* spp.—Swift, pp. 47–48, pl. 4, figs 12–16.
1995   *Prioniodina*? sp.—Swift, p. 48, pl. 4, fig. 17.

Derivatio nominis. According to the occurrence in Great Britain.

Holotypus. The specimen figured by Swift (1995: pl. 3, fig. 2), Department of Geology, Leicester University.

Locus typicus. Downhill Quarry, West Boldon, Sunderland, England.
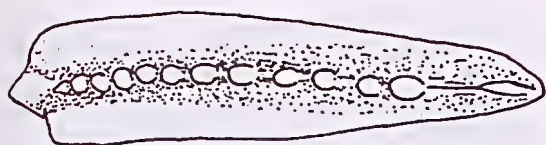
Fig. 5. *Mesogondolella britannica* sp. nov., upper view, holotype, drawing after a photograph illustrated by Swift (1995: pl. 3, fig. 2), Marl Slate (lowermost Zechstein, lower Dzhulfian), sample DHQ1, Downhill Quarry, West Boldon, Sunderland, England. × 80.

Fig. 6. *Mesogondolella britannica* sp. nov., lateral view, drawing after a photograph illustrated by Swift (1995: pl. 3, fig. 12), Marl Slate/Raisby Formation transition beds (lowermost Zechstein, lower Dzhulfian), sample EH7, Eldon Hill Quarry, Durham, England. × 80.

Fig. 7. *Mesogondolella britannica* sp. nov., upper view of the posterior end of a specimen with rounded button, drawing after a photograph illustrated by Swift (1995: pl. 3, fig. 3), Marl Slate (lowermost Zechstein, lower Dzhulfian), sample DHQ1, Downhill Quarry, West Boldon, Sunderland, England. × 80.

Stratum typicum. Marl Slate (lowermost Zechstein, lower Dzhulfian), sample DHQ1.

Diagnosis. Adult Pa elements are symmetrical, have parallel to subparallel margins in the posterior half of the unit, and taper slowly and gradually in the anterior half. The posterior margin is broadly rounded or obliquely blunt, and has a pointed to round button, on which the posterior part of the distinct cusp is situated. The carina has 10–13 denticles that are densely spaced in the posterior part and widely spaced in the anterior part. They are low in the entire carina. Keel trough-like excavated. Loop terminal, posterior end blunt. Other elements of gondolellid type.

Description. Juvenile Pa elements have a pointed posterior end and are widest in or somewhat behind the midlength of the unit. Intermediate stages have a pointed to narrowly rounded or blunt end with a pointed button. They are widest in or somewhat behind the midlength and have subparallel sides in the posterior half of the platform.

Adult forms have a symmetrical, laterally unbowed platform, with parallel or subparallel sides of the posterior half of the platform. The greatest width is at the beginning of the posterior third of the unit, but the platform is of the same or nearly of the same width throughout much of its posterior half. The anterior half of the platform tapers slowly and gradually. The posterior margin of the platform is broadly rounded or obliquely blunt and has a pointed to rounded button. This button is partly formed by the widened base of the posterior part of the cusp (pointed button) or by a very narrow rudimentary platform that is growing around the base of the posterior half of the cusp (rounded button). The platform reaches only until the anterior part of the cusp, the posterior part of the cusp always overreach the platform margin. A brim is never present. The platform margins are only slightly upturned and have a honeycomb microsculpture. The adcarinal furrows are narrow and smooth. The carina bears 10–13 low, discrete denticles; the posterior 5–6 are densely spaced, the anterior denticles are widely spaced. The length of the denticles varies only slightly, lowest are the middle denticles, but the posterior denticles are only insignificantly longer, the anteriormost or the two anterior denticles are slightly longer than the middle ones. The cusp is distinct, small to moderately large, but in lateral view rather broad, triangular. It is erect to posteriorly inclined. The keel is trough-like excavated. The loop is terminal, its posterior margin is, in general, blunt, only in juvenile forms is it rounded or narrow.

The ramiform elements are of the same type as in all gondolellid conodonts. The Pb element is ozarkodiniform (*Ozarkodina tortilis* group morphotype), the M element is cypridelliform (*Cypridodella muelleri* group morphotype), the Sa element is hibbardelliform (*Hibbardella magnidentata* group morphotype), the Sb element is enantiognathiform (*Enantiognathus ziegleri* group morphotype) and the Sc element is metaprioniodiform (*Metaprioniodus suevicus* group morphotype; see Remarks).

Occurrence. Lower Dzhulfian lowermost Zechstein of England. Upper Dzhulfian upper Chhidru Formation of Nammal Nala, Pakistan (material Wardlaw). In the upper Chhidru Formation it occurs together with *Iranognathus tarazi* Kozur,

Mostler & Rahimi-Yazd, *I. unicostatus* Kozur, Mostler & Rahimi-Yazd, advanced *Iranognathus* sp. nov. Wardlaw, transitional to *I. sosioensis* Kozur & Mostler, and *Stepanovites dobruskinae* Kozur & Pjatakova. *I. tarazi*, *I. unicostatus* and *S. dobruskinae* are typical Dzhulfian species that are partly also present in the Dorashamian. *I.* cf. *tarazi* occurs also in the Capitanian. *I. sosioensis* is an upper Dorashamian species (Kozur & Mostler 1996), *Iranognathus* sp. nov. Wardlaw is common in the Capitanian to lowermost Dzhulfian. From this distribution of the accompanying conodonts a (late) Dzhulfian age is indicated for the sample with *Mesogondolella britannica*. Similar, probably identical forms (formerly assigned to *M. rosenkrantzi*) occur also in the lower Dzhulfian of Iran and Transcaucasia (Kozur 1995a) together with *Clarkina leveni* (Kozur, Mostler & Pjatakova). Thus, all occurrences of *M. britannica* indicate a Dzhulfian age.

Remarks. Mesogondolella britannica sp. nov. belongs to the *Mesogondolella phosphoriensis* lineage that is one of the temperate to cool-water *Mesogondolella lineages* (the other is the *M. siciliensis* lineage). The following development can be observed in the *M. phosphoriensis* lineage: *M. idahoensis–M. phosphoriensis–M. rosenkrantzi* n. subsp.–*M. rosenkrantzi rosenkrantzi–M. britannica*. This lineage is important for the subdivision of the temperate to cold-water Middle and Upper Permian. The oldest discussed species of the *M. phosphoriensis* lineage, *M. idahoensis* (Youngquist, Hawley & Miller), is a guideform of the Kungurian. It occurs there from tropical to cool-water or cool-temperate faunas. But already in this time, *M. idahoensis* is better cool-water adapted than most other conodont species of that age. As shown by Kozur (1995a) and Nicoll & Metcalfe (1997), close to the lower water-temperature boundary only *Vjalovognathus* and *Hindeodus* are present. In the next warmer, but also relatively cool environments, *Vjalovognathus* and *Hindeodus* are accompanied by *Mesogondolella idahoensis*. In the next warmer interval, *Neostreptognathodus leonovae* Kozur is additionally present. In warm-temperate climate all subtropical–tropical species are present beside *Vjalovognathus* and the other before mentioned taxa. In subtropical–tropical conodont faunas, the same tropical–subtropical species occur without *Vjalovognathus*. Beginning with the Middle Permian, the species of the *M. phosphoriensis* lineage are restricted to temperate to cool water including cool or cold bottom-water in open-sea tropical areas with palaeopsychrospheric ostracod faunas (Kozur 1991a).

The *M. phosphoriensis* lineage is a taxonomically very difficult group. This is well recognisable by the fact that the same material of *M. britannica* Pa elements was by Swift & Aldridge (1986) assigned to *Neogondolella* aff. *idahoensis*, but by Swift (1995) to *Mesogondolella phosphoriensis*, despite the fact that it does not coincide with both of these considerably older species. In the following discussion only the Pa element of the compared species will be discussed because the other elements are identical or very similar in all gondolellid species, and have no importance for species discrimination in gondolellid conodonts. The assignment of these elements by Swift (1995) will be discussed later.

In the Kungurian *M. idahoensis*, the platform is widest close to the posterior end, parallel-sided in the posterior third, and gradually narrowing in the anterior two-thirds of its length. This outline is similar to that of *M. britannica*, but in this species the parallel or subparallel sides continue in most specimens until the mid-length of the platform. However, adult *M. idahoensis* never have a button at the blunt posterior end, and the platform reaches until the posterior end of the cusp. The number of denticles is much higher in adult specimens (14–19) because the denticles are also densely spaced in the anterior half of the carina, where they are widely spaced in *M. britannica*.

The platform in the Roadian to middle Wordian *M. phosphoriensis* (Youngquist, Hawley & Miller) is slightly asymmetrical (laterally bowed) and widest around the midlength of the unit. From there, it narrows rather abruptly towards the anterior end and slightly towards the rounded or blunt posterior end. The platform reaches until the posterior end of the cusp and mostly a small, rarely a broad, rim is present behind the cusp. A small button at the posterior end of the platform is only exceptionally present. The carina of adult specimens has 11–15 denticles. The loop has mostly also in adult forms a round posterior end.

Most similar to *M. britannica* is the upper Wordian *M. rosenkrantzi* n. subsp. (Kozur & Wardlaw, in prep.) that replaces totally *M. phosphoriensis* in the Retort Shale Member of the Phosphoria Formation. *M. rosenkrantzi* n. subsp. has a very similar outline with a broadly rounded to blunt posterior margin that has, however, no button. The platform reaches until the posterior end of the cusp, but a brim is mostly absent. The platform is slightly asymmetrical by lateral bowing. It is widest at the beginning of the posterior third, but because of subparallel to parallel sides in the posterior third, this entire posterior third of the platform has nearly the same width. The platform narrows gradually

and slowly in its anterior two-thirds. Some forms are subtriangular, but not so pronounced as in *M. rosenkrantzi rosenkrantzi* (Bender & Stoppel). The number of denticles on the carina is high (up to 18 in adult forms), with 6–8 very densely spaced denticles in the posterior part of the carina. Thus, the main differences of *M. rosenkrantzi* n. subsp. to *M. britannica* are: (1) missing button on the posterior margin, the platform reaches until the posterior end of the cusp; (2) larger number of denticles; and (3) slight asymmetry of the platform by lateral bowing.

The Capitanian (? and lower Dzhulfian) *M. rosenkrantzi rosenkrantzi* (Bender & Stoppel) is mainly distinguished by the distinct triangular platform outline of adult forms and by missing button on the posterior margin. Moreover, a narrow platform brim is often present behind the cusp. These features in juvenile to subadult forms are hard to distinguish.

B. britannica is distinctly different from other Lopingian conodonts (except its forerunner *M. rosenkrantzi rosenkrantzi*) by its outline and the trough-like excavated keel. Therefore, it may be the end form of the *M. phosphoriensis* line. However, some early representatives of the *Clarkina carinata* group from Greenland have a surprisingly similar outline and a somewhat excavated keel (e.g. the specimen figured by Sweet 1976 on pl. 16, fig. 14). Moreover, a button is characteristic for many species of the *C. carinata* group and become in this group even more pronounced or changes in a posterior constriction of the platform. Thus, it cannot be excluded that the *C. carinata* group has evolved from *M. britannica*.

As mentioned above, the gondolellid taxonomy is based exclusively on the Pa elements because the other elements are identical or very similar in all gondolellid conodonts. For completeness of the knowledge of *M. britannica*, the assignment of the different elements by Swift (1995) will be discussed below.

The Pb element of *M. britannica*, in the form-taxonomy belonging to the *Ozarkodina tortilis* group, was determined by Swift (1995) as the P element of *Xaniognathus abstractus* (Clark & Ethington). A broken form of this Pb element was determined by Swift (1995) as *Xaniognathus* spp., P element. Juvenile Pb elements of *M. britannica* he determined as *Xaniognathus* spp., Pb element.

The M element of *M. britannica*, in the form-taxonomy belonging to the *Cypridodella muelleri* group, was correctly assigned as M element, but of ?*M. phosphoriensis*.

The Sa element, belonging in the form-taxonomy to the *Hibbardella magnidentata* group, was assigned by Swift (1995) as Se element to *Xaniognathus abstractus* (Clark & Ethington). A nearly complete posterior bar was figured. Such broken posterior bars of *'Hibbardella' magnidentata* (Tatge) were in the Triassic described as *'Prioniodella' prioniodellides* (Tatge) as already assumed by Kozur (1968) and recognised by Kozur & Mostler (1972).

The Sb element, belonging in the form-taxonomy to the *Enantiognathus ziegleri* group, was assigned as Sb element to ?*M. phosphoriensis* by Swift (1995).

Broken parts of the Se element, belonging in the form-taxonomy to the *Metaprioniodus suevicus* group, were assigned as ?Pb element (broken part of the posterior bar) or as Sa element (broken specimens with cusp and short parts of the anterior and posterior bar) to ?*M. phosphoriensis*. These two preservations are very typical for *Metaprioniodus suevicus* (Tatge), the Se element of many gondolellid conodonts (Kozur 1968; Kozur & Mostler 1972). The very fragmentary element that Swift (1995) assigned to a Se element of ?*M. phosphoriensis*, is surely not a Se element, but it is too fragmentary for recognition, which element of *M. britannica* it is.

Merrillina Kozur, 1975, *Stepanovites* Kozur, 1975 and *Sweetina* Wardlaw & Collinson, 1986

Wardlaw & Collinson (1986) assigned *Stepanovites meyeni* Kozur & Movshovich, 1975, the type species of *Stepanovites* Kozur, 1975 to *Merrillina divergens* (Bender & Stoppel, 1995). For an apparatus identical with that of *Stepanovites*, they introduced *Sweetina* Wardlaw & Collinson, 1986 with the type species *Sweetina triticum* Wardlaw & Collinson, 1986 = *Stepanovites festivus* (Bender & Stoppel) *sensu* Wardlaw & Collinson (1984). In this genus, the Pa element has a short and anteriorly directed lateral process. This Pa element is very rare and was not found by Kozur & Movshovich (in Kozur 1975).

Chalimbadja & Silantiev (1997; photographs only shown as poster on the Strzelecki Symposium in Melbourne), found in Lower Kazanian beds in a monospecific fauna the typical *Sweetina* Pa element together with the apparatus of *Stepanovites meyeni*. The very characteristic Se element of this lower Kazanian species was found also in the lower Kazanian material of Chalimbadja & Silantiev (1997). However, because of the Pa element, they assigned this form to *Sweetina triticum*, but the

apparatus is different from this species (but congeneric). The important and rich material by Chalimbadja & Silantiev (1997) has proven that *Sweetina* Wardlaw & Collinson, 1986 is a junior synonym of *Stepanovites* Kozur, 1975, as the type species *S. meyeni* has the characteristic Pa element with anteriorly directed short lateral process.

Chalimbadja & Silantiev (1997) assigned erroneously upper Kazanian forms to *S. meyeni*, from which they did not find a Pa element. The Sc element is very different from that of *S. meyeni*, and therefore these forms do not belong to *S. meyeni*, the holotype of which was derived from the Lower Kazanian. This form has probably a symmetric Pa element (figured together with a real Pa element of *Merrillina* under *M. divergens*) with a central cusp and short anterior and posterior bars of equal length that bear two denticles. It belongs probably to a new genus that is closely related to *Stepanovites*, but distinguished by the missing lateral process of the Pa element. Neither this new genus nor *Stepanovites* emend. belong to *Merrillina*. The entire apparatus of *Stepanovites* and of the new genus is considerably more robust than any *Merrillina* apparatus, and the Pa element is basically different.

Merrillina divergens that was reported by Chalimbadja & Silantiev (1997) from the upper Kazanian, does not belong to this species. The Pa element has a rather low blade, widely separated denticles and a small denticle behind the cusp. In the Sb element, the posterior end of the posterior bar is nearly vertically downward-directed, and this part also bears denticles. This is a primitive feature of *Merrillina*, indicating that *Merrillina* n. sp. from the upper Kazanian is considerably older than the Zechstein *M. divergens*. The youngest beds in North America, where this primitive type of *Merrillina* Sb element was found, is the upper, but not uppermost Wordian (Wardlaw & Collinson 1986). Therefore, the upper Kazanian probably does not reach up to the top of the Wordian. If this tentative correlation will be confirmed by discovery of *Merrillina* sp. nov. and the new conodont species (and genus?) of the upper Kazanian in well dated rocks outside the Russian Platform, then the Tatarian would begin within the Wordian, if there is no gap between the Kazanian and Tatarian.

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